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Opto-Thermal Frequency Modulation of Phase Change Micro-Electro-Mechanical Systems

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Abstract : Here we demonstrate mechanical detection of photo-induced Insulator to metal transition (MIT) in ultra-thin vanadium dioxide (VO_2) micro strings by using < 100 µW of optical power. Highly focused laser beam heated the string locally resulting in through plane and along axial heat diffusion. Localized temperature increase can cause temperature rise > 60 ºC. The heated region of VO_2 can transform from insulating (monoclinic) to conducting (rutile) phase leading to lattice compressions and stiffness increase in the resonator. The mechanical frequency of the resonator can be tuned by changing optical power and wavelength. The first mode resonance frequency was tuned in three different ways. A decrease in frequency below a critical optical power, a large increase between 50-120 µW followed by a large decrease in frequency for optical powers greater than 120 µW. The dynamic mechanical response was studied as a function of incident optical power and gas pressure. The resonance frequency and amplitude of vibration were found to be decreased with increasing laser power from 25-38 µW and increased by1-2 % when the laser power was further increased to 52 µW. The transition in films was induced and detected by a single pump and probe source and by employing external optical sources of different wavelengths. This trend in dynamic parameters of the strings can be co-related with reversible Insulator to metal transition in VO_2 films which creates change in density of the material and hence the overall stiffness of the strings leading to changes in string dynamics. The increase in frequency at a particular optical power manifests a transition to a more ordered metallic phase which tensile stress onto the string. The decrease in frequency at higher optical powers can be correlated with poor phonon thermal conductivity of VO_2 in conducting phase. Poor thermal conductivity of VO_2 can force in-plane penetration of heat causing the underneath SiN supporting VO_2 which can result as a decrease in resonance frequency. This noninvasive, non-contact laser-based excitation and detection of Insulator to metal transition using micro strings resonators at room temperature and with laser power in few µWs is important for low power electronics, and optical switching applications.

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